PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

BARKER BRETTELL
138 Hagley Road
Edgbaston
Birmingham B16 9PW
GRANDE BRETAGNE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	12.07.2004
Applicant's or agent's file reference: JL3697	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB 03/01414	01.04.2003	02.04.2002

Applicant: THE UNIVERSITY OF NOTTINGHAM et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international preliminary examining authority:	Authorized Officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Novoa, C Tel. +49 89 2399-2718

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference JL3697	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB 03/01414	International filing date *(day/month/year)* 01.04.2003	Priority date *(day/month/year)* 02.04.2002
International Patent Classification (IPC) or both national classification and IPC C22B1/00		
Applicant THE UNIVERSITY OF NOTTINGHAM et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 8 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
23.10.2003	12.07.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Bjoerk, P Telephone No. +49 89 2399-8452

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB 03/01414

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-5, 7, 9-46	as originally filed
6, 8	filed with telefax on 25.02.2004

Claims, Numbers

1-26	filed with telefax on 25.02.2004

Drawings, Sheets

1/29-29/29	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

   ☐ the drawings, sheets:

5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

   see separate sheet

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	25,26
	No:	Claims	1-24
Inventive step (IS)	Yes:	Claims	25,26
	No:	Claims	1-24
Industrial applicability (IA)	Yes:	Claims	1-25
	No:	Claims	

2. Citations and explanations

   see separate sheet

Re Item I
Basis of the report

1. The application relates to methods and apparatuses of pre-treatment of a multi-phase material prior to a subsequent operation, such as grinding. By applying microwaves for a maximum of 0,5 second, the bond between the phases in the material is weakened by differential expansion of the phases which leads to a lower energy consumption for the subsequent operation.

   Claim 1 features treatment with microwaves of a power density of at least 10^9 Wm^{-3} for a time of 0.5 second or less, followed by passing the material out of the treatment area for a subsequent operation.

   Claim 18 relates to an apparatus adapted to the process of claims 1-17.

   Claim 22 relates to a method of continuous processing of ore or rocks by applying microwaves followed by a mechanical breaking up of the rocks.

   Claim 24 relates to an apparatus adapted to the process of claims 22 and 23.

   Claim 25 relates to a method as in claim 1 with additional features relating to throughput of material, a time of 1 ms or less, pulses of energy and overall bulk temperature.

   Claim 26 features a processing of ore with microwaves for a time of less than 0.1 second.

2. In the amended set of claims filed on 25.02.04, the phrase "for a short enough time to avoid causing substantial chemical changes to one, or both of the phases of the multi-phase material" has been introduced into method claim 1, the similar phrase " a time that is short enough to avoid causing substantial chemical change to the material" into apparatus claim 18 and "at a speed that is fast enough to avoid causing substantial chemical change to the ore or rocks" into method claim 22.

   No basis for these amendments in the application as originally filed have been indicated by the applicant in his letter of 25.02.04. The description does not appear to discuss any link between the time/speed and chemical changes. Only

claims 25 and 26 feature the following phrases:

claim 25: "wherein the temperature of the phases of the multi-phase material is kept low enough to avoid significant changes to the chemical properties of the different phase materials";

claim 26: "applied for a short enough time to cause differential thermal expansion between materials of different phases to cause weakening between phases whilst avoiding causing significant chemical changes to the ore, or at least to the mineral to be extracted."

Claim 26 is an independent claim as indicated above and it relates to the processing of an ore in order to increase the yield of mineral extraction, whereas claims 1, 18 and 25 relate to a general method and apparatus for microwave pretreatment of a multi-phase material. The description cites for example de-husking nuts, drying materials, food processing (page 43, lines 4-11).

The application of the time-chemical changes feature of the specific embodiment of claim 26 to the broad methods and apparatuses of claims 1, 18 and 25 is seen as an amendment going beyond the disclosure in the international application as filed and is therefore contrary to the requirement of Art.34(2)(b) PCT.

The present report is therefore established as if these amendments had not been performed. The other amendments made to the text of the claims, rendering the presence of microwaves compulsory as well as the amendments made to the description on pages 6 and 8 are seen as allowable with regard to Art.34(2)(b) PCT.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

D1: US-A-5 824 133 (TRANQUILLA JAMES M) 20 October 1998 (1998-10-20)
D2: DATABASE WPI Section PQ, Week 198810 Derwent Publications Ltd., London, GB; Class P41, AN 1988-069337 -& SU 1 326 334 A (AS UKR

GEOTECH MECH INST CONS BUR), 30 July 1987 (1987-07-30) 96-01), pages 43-54

D1 corresponds to WO97/34019 cited on page 4 of the description of the present application. In the process of D1, a stream of ore is subjected to microwave energy before subsequent operation such as conventional recovery processes by comminution, roasting, leaching etc. (col.1, l.10-14; col.4, l.7-8). To avoid energy dissipation, the dwelling time in the microwave treatment zone is short, less than 6 sec. and preferably in the area of 0.25 sec. (col.3, l.58-60). A corresponding apparatus is also disclosed (Fig.2). The main purpose of the microwave pre-treatment in D1 appears to be for bringing about metallurgical effects which make the ore more amenable to leaching techniques or which lead to phase transformations (col.1, l.20-35).

D2 discloses pretreatment of ore prior to milling by heating the ore with standing microwaves. The ore is circulated on a conveyor belt through the treatment zone before being fed to the milling unit. The pretreatment destroys the bonding between ore and non-ore phases (Abstract, Figure).

2. As indicated under Item I above, the set of claims is read as not having the features related to the time-chemical changes.

The process disclosed in D1, with a preferred dwelling time of 0.25 sec. is novelty destroying to the subject matter of claims 1 and 22. The apparatus described in D1 contains all the features of claim 18.

The process and apparatus described in D2 is directly novelty destroying to the subject matter of claims 22 and 24. These claims do not refer to any exposure times to the microwave field.

The subject matter of these independent claims does therefore not fulfil the requirements of Art.33(2) PCT.

Regarding the dependent claims, their features are to a large extent to be found in the disclosure of D1.

3. Neither D1 nor D2 discloses microwave treatment times of 0.1 sec. or less. Such short treatment times appear also not to be disclosed as such in the remaining

prior art cited in the International Search Report.

With regard to the method of claim 25, the disclosures of D1 and D2 are not seen as novelty destroying as the overall bulk temperature is not limited to a maximum of 40°C in order not to achieve significant changes to the chemical properties of the material. Such a limitation appears also not to be disclosed as such in the remaining prior art cited in the International Search Report.

4. The set of figures does not fulfil the requirements of Rule 11.11(a) PCT as the figures should in principle not contain any words such as the legends in Figs.5 to 19 and the tables 1 to 8.

We have also appreciated that it is possible to pass material through a microwave cavity in a continuous stream, for a continuous treatment process. The microwave cavity has high electric field which in turn produces high power densities (e.g. 10^{15} Wm^{-3} or 10^{16} Wm^{-3} or more) and material can be made to move through high field strength electromagnetic waves, residing in the high intensity region for only a short time. This has the double benefit of increasing the throughput of materials through the treatment machine, and using the knowledge that we do not need to apply microwaves to materials for very long to achieve the desired effect. The two advantages have synergistic effect.

In some embodiments the method comprises creating a standing wave of microwaves in a cavity and ensuring that the composite material is disposed in the cavity at a position on or about a maximum intensity of the standing wave.

The method may have a guide means which guides the composite material to the position of a maxima of the standing wave.

According to another aspect of the invention we provide a method of weakening the bond between a first phase of material and a second phase of material in a multi-phase composite material comprising applying a high powered density of microwave, or high electric field strength microwaves, to the composite material for an exposure time that is of the order of a ½ or ¼ of a second or less.

the composite material for an exposure time that is of the order of ½ or ¼ second or less.

According to another aspect of the invention we provide a method of continuous processing of ore or rocks comprising applying high electric field strength microwaves to create high power densities, on a continuous basis to ore or rocks passing through a microwave cavity or zone to weaken the ore or rocks, and subsequently passing the continuous flow of ore or rocks to a mechanical treatment machine and mechanically breaking up the ore or rocks.

The microwaves may be pulsed, and applying them on a continuous basis is not meant to exclude repeated pulses of microwaves.

A reduction in overall energy consumption - quite a serious reduction - may be available if we pre-treat the ore or rocks with microwaves so as to weaken them and then break them up in a mechanical comminution process.

Moreover, a continuous process has a higher throughput, and can cope with higher volumes than batch processes. This makes the process even more economically attractive.

It is particularly elegant that once we have a high enough electric field strength we can then flow material (whether that be for weakening the bond between different phases, or other purposes) through the microwave field in a continuous manner at a rate that is fast enough to expose the material to the high intensity microwave for only a short time, (e.g. ½ or

10/509988
DT05 Rec'd PCT/PTO 30 SEP 2004

CLAIMS

1. A method of microwave pre treatment of a multi-phase material prior to a subsequent operation on the material, the material having a first phase of material and a second phase of material, the method comprising heating the material with microwaves, producing a power density of at least $10^9 Wm^{-3}$ in a continuous process in which the material moves into and through a microwave treatment area and experiences exposure to microwaves, in the treatment area for a time of the order of ½ second or less, for a short enough time to avoid causing substantial chemical changes to one, or both of the phases of the multi-phase material, and passing the material out of the treatment area for said subsequent operation.

2. A method according to claim 1 wherein said material experiences microwaves in said treatment area for a time of the order of (i) 0.1 second or less; (ii) 0.01 second or less; or (iii) 0.001 second or less.

3. A method according to claim 1 or claim 2 wherein pulses of microwaves, are emitted substantially continuously and the pulses have a duration of the order of (i) 1μs or less; or (ii) 10μs or less; or (iii) 100μs or less; (iv) 1ms or less; (v) 10ms or less; 100ms or less.

4. A method according to claim 3 wherein the substance, whilst in the treatment area, experiences a series of pulses of energy, said series having a number of pulses of the order of: (i) 100 pulses or more; (ii) 50 pulses or more; (iii) 10 pulses or more; (iv) 5 pulses or more; (v) 2 pulses or more; (vi) one pulse.

5. A method according to any preceding claim wherein the power density produced by the microwaves in the treatment area is of the order of (i) $10^{15}Wm^{-3}$ or more; or (ii) $10^{16}Wm^{-3}$ or more.

6. A method according to any preceding claim wherein the bulk temperature of the material is raised by less than 200°C, and preferably less than 150°C.

7. A method according to claim 6 wherein the bulk temperature of the material is raised by of the order of, or less than: (i) 50°C; (ii) 20°C; (iii) 10°C.

8. A method according to any preceding claim wherein said material flows through said treatment area at a rate of at least 100 tonnes an hour.

9. A method according to claim 8 wherein said material flows through said treatment area at a rate of the order of 1000 tonnes an hour or more.

10. A method according to any preceding claim wherein the first phase comprises a desired mineral and the second phase a rock substrate surrounding the mineral, and wherein the microwave energy significantly weakens the bond strength between the mineral and the surrounding substrate by causing local differential thermal expansion.

11. A method according to claim 10 wherein the energy is applied to the material for a short enough time to avoid causing substantial chemical changes to (i) the mineral; and/or (ii) both the material and substrate, that would detrimentally influence the efficiency of subsequent separation of the mineral and substrate.

12. A method according to any one of claims 1 to 10 wherein the first phase comprises a mineral and the second phase comprises water, and wherein said pre-treatment comprises dehydration, said electromagnetic energy drying said mineral.

13. A method according to claim 12 wherein the microwaves also cause directly or indirectly fracturing or weakening of the mineral.

14. A method according to claim 12 or claim 13 wherein said first phase comprises (i) coal; or (ii) other hydrated mineral.

15. A method of separating a mineral from an ore comprising pre-treating the ore in accordance with any one of claims 1 to 11 and subsequently comminuting the ore, preferably by grinding or milling, or crushing.

16. A method according to any preceding claim wherein the power density within the treatment area produced by the microwaves is from the group: of the order of 10^{10} Wm^{-3}, or more; 10^{11} Wm^{-3}, or more; 10^{12} Wm^{-3}, or more; 10^{13} Wm^{-3}, or more, 10^{14} Wm^{-3}, or more; 10^{15} Wm^{-3}, or more.

17. A method of recycling articles which have parts made of different materials in them comprising pre-treating the articles in accordance with any one of claims 1 to 9 and then mechanically stressing the articles in order to break then up and facilitate the extraction of parts of the articles.

18. Apparatus for microwave treatment of material comprising:

a microwave treatment zone;

a microwave emitter disposed at said treatment zone;

a material transporter adapted to transport material through the treatment zone; the arrangement being such that:-

the emitter is adapted to emit microwaves that create a power density of at least $10^9 Wm^{-3}$, preferably 10^{15} or above;
and the material transporter is adapted to transport said material through the treatment zone fast enough so that said material experiences significant microwaves in said zone for a time of the order of ½ second or less, a time that is short enough to avoid causing substantial chemical change to the material.

19. Apparatus according to claim 18 adapted to cause said material to experience microwaves for a time of the order of (i) 0.1 second or less; or (ii) 0.01 second or less; or (iii) 0.001 second or less.

20. Apparatus according to claim 18 or claim 19 adapted to transport of the order of 1000 tonnes of material an hour through the treatment zone.

21. Apparatus according to any one of claims 18 to 20 wherein said emitter is adapted to produce microwave pulses with a duration of the order of a microsecond, or tens of microseconds, or hundreds of microseconds, or less, the material preferably receiving a plurality of pulses, and preferably many pulses, whilst it is in the treatment zone.

22. A method of continuous processing of ore or rocks comprising applying high power density microwaves, or high/electric field strength microwaves, on a continuous basis to ore or rocks passing through a microwave cavity or zone to weaken the ore or rocks at a speed that is fast enough to avoid causing substantial chemical change to the ore or rocks, and subsequently passing the continuous flow of ore or rocks to a mechanical treatment machine and mechanically breaking up the ore or rocks.

23. A method according to claim 22 wherein the exposure of the ore or rocks to the high field strength microwaves is of the order of half a second or less, or a quarter of a second or less, or 0.1 second or less, or 0.01 seconds or less.

24. Apparatus for continuous processing of ore or rocks comprising means for applying high power density microwaves, or high electric field strength microwaves, on a continuous basis to ore or rocks passing through a microwave cavity or zone to weaken the ore or rocks and feed means adapted to pass subsequently the continuous flow of ore or rocks to a mechanical treatment machine adapted mechanically to break up the ore or rocks.

25. A method of microwave pre-treatment of a multi-phase material prior to a subsequent operation on the material to extract one material from the others, the method comprising providing a continuous feed of the multi-phase material through a region in which applied microwave radiation is present, at a speed to allow a throughput of multi-phase material of at least 500 tonnes per hour, the microwave radiation creating a power density of at least 10^{13} Wm^{-3}, the material experiencing microwave radiation for a time of the order of 1ms or less, during which time it experiences one or a plurality of pulses of energy, preferably having a pulse duration of the order of microseconds or less, and wherein the overall bulk temperature of the multi-phase material does not rise by more than 40°C, and wherein thermal stress is created between phase boundaries which is large enough to cause inter phase fracturing, and wherein the temperature of the phases of the multi-phase material is kept low enough to avoid significant changes to the chemical properties of the different phase materials.

26. A method of increasing the yield of a mineral extracted from an ore having a plurality of phases of materials comprising causing weakening of inter-phase boundaries by exposing the ore to high field strength microwaves for a time of less than 0.1 or 0.01 second, the microwaves having a high enough field strength and being applied for a short enough time to cause differential thermal expansion between materials of different phases to cause weakening between phases whilst avoiding causing significant chemical changes to the ore, or at least to the mineral to be extracted.